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ARMOUR RESEARCH FOUNDATION OF ILLINOIS INSTITUTE OF TECHNOLOGY

TECHNOLOGY CENTER

ARF Project B241

FIBER-REINFORCED METALS AND ALLOYS

for

Chief, Bureau of Naval Weapons
Department of the Navy
Washington 25, D. C.

NOTE: Effective June 1, 1963, the name of Armour Research Foundation of Illinois Institute of Technology will change to IIT RESEARCH INSTITUTE.

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ARMOUR RESEARCH FOUNDATION
of
ILLINOIS INSTITUTE OF TECHNOLOGY
Technology Center
Chicago 16, Illinois

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FIBER-REINFORCED METALS AND ALLOYS

ARF-B241-6

(Bimonthly Report No. 6)

February 4 to April 4, 1963

for

Chief, Bureau of Naval Weapons
Department of the Navy
Washington 25, D. C.

Attn: Code RRMA-222

May 3, 1963

FIBER-REINFORCED METALS AND ALLOYS

I. INTRODUCTION

This is the sixth bimonthly report on ARF Project No. B241, entitled "Fiber-Reinforced Metals and Alloys," and covers the work done from February 4 to April 4, 1963.

The work performed in the past under Bureau of Naval Weapons sponsorship developed some basic criteria required for efficient scientific design of useful fiber-reinforced composites. The objective of the current program is, therefore, to apply these principles in developing composites of high strength-to-weight ratios and high elastic moduli. The fiber material is beryllium and to date its reinforcing properties have been investigated in matrices of silver and silver alloys. The composites are prepared either by mixing powdered matrix material with the beryllium fibers and then hot extruding the green compact, or by casting and extruding. Present efforts are concerned with composites of beryllium fibers with aluminum powder and with pre-alloyed aluminum powder.

II. EXPERIMENTAL PROCEDURE

The previous report (ARF B241-5, December 4, 1962 to February 4, 1963) described and discussed the two types of beryllium fibers used in this work. The present tests were made with Huyck Corporation fibers. The aluminum powder was prepared by atomizing molten 2S aluminum in a high-pressure blast of air. In the same manner, 7075 aluminum alloy powder was prepared. The powders were sieved through a 60 mesh screen and mixed with a measured proportion (by volume) of beryllium fibers. The mixture was cold-compacted in a 1 inch diameter die. The compact was then dropped into a preheated extrusion die, allowed to attain the extrusion temperature, and extruded through a 18:1 or a 40:1 reduction ratio. The extruded material was tensile tested and metallographically examined.

III. RESULTS AND DISCUSSION

The results of a series of tests on beryllium fiber-aluminum powder composites are shown in Table I. The chemical composition of the composites was between 10 and 50 volume per cent of beryllium. The extrusion temperature was in the region of 1000°F and the extrusion reduction ratio was either 18:1 or 40:1. The material was tested in the as-extruded condition.

It is apparent from Table I that there is no identifiable dependence of tensile strength on beryllium content. This is surprising since previous results showed a linear increase in strength with increasing beryllium fiber content. Although the beryllium in the present tests increases the strength of the composites to about twice that of the beryllium-free aluminum (UTS about 10,000 psi), there is not a spectacular increase to the strength levels we wish to attain (100,000 psi or better). As the beryllium content is raised the composites become progressively more brittle so that 50 volume per cent composites extruded through the 40:1 reduction die are severely cracked.

Microexamination of the composites revealed that the fibrous nature of the beryllium particles had been largely destroyed (Figures 1 and 2). Little or no elongation of the fibers occurred, but they are apparently broken up and then coagulated into irregular shaped masses (Figure 2), the degree of coagulation increasing with increasing beryllium content and increasing extrusion ratio. Moreover, these coagulated masses appear to be nuclei for the formation of large particles of a third, hard, black phase. Fracture in these materials seems to be initiated by separation of the matrix from particles of the third phase, and this obviously controls the strength of the composites and explains why the strength of these composites becomes independent of beryllium content.

The particles are very hard and, during metallographic preparation of the specimens, are usually torn from their seats leaving voids which on a small scale are very easily mistaken for porosity. The phase is thought to be an oxide product formed by reaction between the beryllium and the Al_2O_3 from the surfaces of the aluminum powder. A microhardness indentor failed to make an impression on it. Whatever it is, the presence of this phase is detrimental and unwanted.

The observation that the beryllium fibers are broken into smaller particles in the above composites suggested that beryllium powder-aluminum powder composites should give similar test data. The results obtained on two such composites made from -100 mesh beryllium powder are given in Table II. There is an improvement in strength over the corresponding fiber composites. Also, much less of the black phase was observed.

Composites of beryllium fibers and beryllium powders with a heat-treatable 7075 aluminum alloy were also extruded and tested. 7075 alloy has a lower melting temperature than aluminum, and hence, lower extrusion temperatures had to be used. Tables III and IV show the strengths obtained on the as-extruded materials. In the as-extruded condition the 7075 alloy is in its solution-treated (i. e., its softest) state. Further tests will be made on the age-hardened material. It is clear from a comparison of Tables III and IV with Tables I and II that these aluminum alloy composites offer more scope for the attainment of higher strength levels than do the plain aluminum composites. There is also an indication that the use of beryllium powder shows an improvement over the presently used fibers. From the metallographic standpoint the black phase noted in the plain aluminum composites is almost absent in the 7075 aluminum composites (both fiber and powder). Figure 3 shows the microstructure of an as-extruded, 30 volume per cent beryllium powder-7075 alloy composite. Close scrutiny reveals only small traces of the black phase in the beryllium aggregates.

IV. FUTURE WORK

Further work will be carried out on the heat-treatable aluminum alloy composites in the as-extruded and age-hardened conditions. Other matrix alloys will also be tested and in this respect it is hoped to develop some high strength, low density, aluminum alloys by powder metallurgy techniques.

V. LOGBOOKS AND CONTRIBUTING PERSONNEL

The data herein are recorded in Logbooks No. C-11179 and C-13158. N. M. Parikh, K. Farrell (Associate Metallurgist) and M. Malatesta (Assistant Experimentalist) contributed to this program.

Respectfully submitted,

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TABLE I

TENSILE STRENGTHS OF SOME BERYLLIUM FIBER-ALUMINUM POWDER EXTRUDED COMPOSITES

Composition, vol % beryllium	Extrusion Temp., °F	Reduction Ratio	Tensile Strength, X1000 psi
Al + 10% Be	975	18:1	21.8
Al + 10% Be	990	40:1	28.9
Al + 30% Be	925	18:1	20.2
Al + 30% Be	1050	40:1	18.4
Al + 50% Be	950	18:1	17.2
Al + 50% Be	1050	40:1	Cracked during extrusion.

TABLE II

TENSILE STRENGTHS OF SOME BERYLLIUM POWDER-ALUMINUM POWDER EXTRUDED COMPOSITES

Composition, vol % beryllium	Extrusion Temp., °F	Reduction Ratio	Tensile Strength, X1000 psi
Al + 30% Be	975	18:1	25.6
Al + 50% Be	975	18:1	33.9

TABLE III

TENSILE STRENGTHS OF SOME BERYLLIUM FIBER-7075 ALUMINUM ALLOY EXTRUDED COMPOSITES

Composition, vol % beryllium	Extrusion Temp., °F	Reduction Ratio	Tensile Strength, X1000 psi
7075 alloy + 10% Be	860	18:1	38. 4
7075 alloy + 30% Be	870	18:1	40:1
7075 alloy + 50% Be	875	Partial Melting	

TABLE IV

TENSILE STRENGTHS OF SOME BERYLLIUM POWDER-7075 ALUMINUM ALLOY EXTRUDED COMPOSITES

Composition, vol % beryllium	Extrusion Temp., °F	Reduction Ratio	Tensile Strength, X1000 psi
7075 alloy + 10% Be	850	18:1	45. 4
7075 alloy + 30% Be	870	18:1	53. 5
7075 alloy + 50% Be	850	18:1	44. 4

Neg. No. 24893 X160

FIG. 1

Microstructure of Al-10% vol. Be fiber composite hot-extruded through a 40:1 reduction.

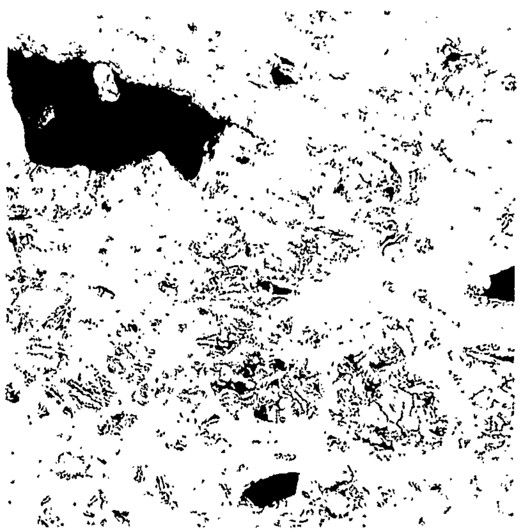

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FIG. 2

Microstructure of Al-30% vol. Be fiber composite hot-extruded through a 40:1 reduction.

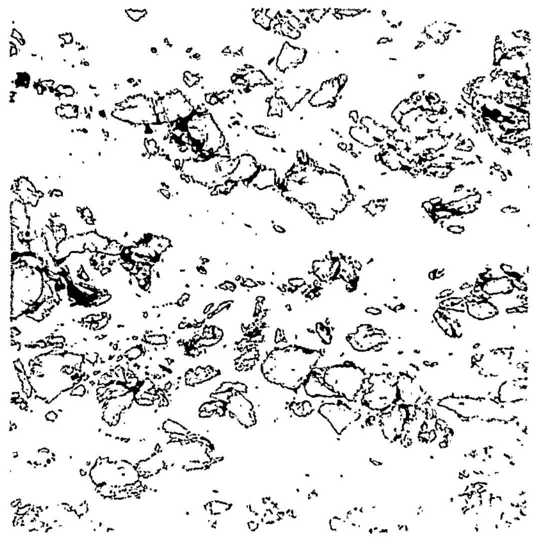

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FIG. 3

Microstructure of 7075 alloy - 30% vol. Be powder composite hot-extruded through a 40:1 reduction.